An Ontological Win-Win Model for Requirements Negotiation: Visual Decision-Making Aid for Software Development Teams

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Abstract

Requirements negotiation in the domain of software development often runs into communication obstructions caused by the different worlds in which software engineers in software development firms and project managers in client firms exist. Toward a solution to situations of this kind, Grünbacher's Easy Win-Win model presents a limited reformulation of the general win-win approach, which emphasises the collaborative construction of a common lexicon, or dictionary of agreed-upon terms with definitions. An ontological model also exists in conceptual form, representing a philosophically informed approach to reducing complex points of interpretation to visual imagery, with the potential for a more intuitive basis for common understanding than that afforded by a lexicon. This paper presents an augmented version of Grünbacher's Easy Win-Win model for application specifically within the context of software requirements negotiation, to support future testing to assess its effect on communication effectiveness and efficiency.

Keywords

lexicon, ontology, project management, requirements negotiation, Win-Win negotiating

INTRODUCTION

One of the most important sources of conflict in requirements negotiation (RN) is the failure on the part of one or more parties to identify accurately the kind of knowledge to seek (Bera et al. 2011). This phenomenon raises the importance of more than merely having knowledge of the processes associated with software development, because each new innovation implicates new relationships among one or more of the known parameters under consideration. How is a party to an ongoing negotiation over a complex product to know how newly emergent parameters may affect previously negotiated parameters? While it is possible to conjecture that negotiators must simply continue to study all agreed-upon elements of an evolving set of contractual specifications, it is infeasible to expect an endlessly repeated study of previously settled elements of discussion, even if the circumstances happen to afford the time and leisure to do so.

Software requirements negotiation implies sufficient knowledge of the underlying technical parameters of the application framework in question to inform appropriate decision making with an understanding of appropriate constraints. The minimum level of familiarity with the underlying application framework consists of knowing what classes of information require instantiation in the new application in order to achieve a particular kind of functionality (Recio-Garcia et al. 2009). However, as the number of subsidiary elements of the application framework increases, the potential interactions among them and hence the application's complexity increase geometrically. Before long, the complexity of the application framework exceeds the ability of human beings to master the requisite knowledge and in turn negotiate efficiently.

The Win-Win Approach to Negotiation

The search for win-win outcomes in complex negotiation, in which multiple attributes emerge in the decision-making process, creates immense challenges for negotiators (Lai and Sycara 2009). For this reason, there is already a broad base of ongoing research in progress to improve knowledge management system (KMS) structures and database criteria to accommodate the production of more accurate outcomes through automated processes (Hallett et al. 2007; Ko and Dennis 2011; Ma and Harmon 2006). Thus, the win-win model may benefit from automation, or else simply guide human beings in face-to-face negotiating. The win-win model has already been useful in a wide array of actual cases, ranging from the lower-order but admittedly sensitive challenges of healthcare management (Guo 2011) to high-level negotiations in mergers and acquisitions (Konstantopoulos et al. 2009). There is therefore no question that the win-win approach is effective in general.

For the sake of comparison, the win-win model is advisable where the expectation exists of future negotiations with the same parties, while win-lose is often advisable with purely economic objectives and no expectation of an ongoing relationship (Belsey 2010). Several other models, including REBC, RADPAC, and RAEQOBSF, constitute variations of the win-win model but focus primarily on the canonical steps to take in a negotiating session, as indicated by each respective acronym (Jevremovič 2011). Of the available models, only Grünbacher's (2000) adaptation of the win-win model features the significant element of developing a taxonomy to aid in communicating complex subjects across teams coming from disparate industrial backgrounds. Thus, while other negotiating models may serve certain strategic purposes in requirements negotiation for software development, the win-win model tends to be optimal in this setting.

The Ontological Approach to Negotiation

While the ontological approach to conceptual modelling has a long history, its applications in support of intuitive layouts to facilitate user behaviour in web-based interaction is relatively new (Bera et al. 2011). In this kind of application, a visual ontology is a map of concepts that follows formal parameters for selecting the elements to include among the map's essential symbols, such that the planner or designer leaves no key element out of it. It is more precise, with a specific application to the search for knowledge, than is the case with a standard map or illustration of any kind that merely tries to reduce the total symbology necessary to depict ideas. Thus, while a conceptual map mainly tries to achieve parsimony, by displaying maximal information with minimal symbols, a visual ontology uses a parsimonious design to display all essential knowledge categories, to guide the knowledge search itself. Ontologies of this kind obey the formal rules of epistemology (*cf*. Bannon 2009; Michel 2009).

From another perspective, an ontology is a shared representation of concepts emerging from agreed-upon protocols among interested parties (Pinto et al. 2009). So defined, ontologies may operate both in computerised form and as conceptual maps to guide collaborators, especially if the object of collaboration is software. In this application, software-oriented ontologies serve as the foundation for translating human decisions into machine-operability. Ontologies are therefore useful as a way to represent structural criteria to guide the entire software development process. They simultaneously serve the purpose of developers in simplifying and harmonising the necessary language of collaboration, while enabling efficient translation of the resulting developmental criteria into machine-readable language (Gurevich et al. 2009).

Applied to software product performance, the distinction between tool-oriented assumptions and ontological assumptions as a guide in requirements negotiation is visible along several dimensions (Niculescu and Trausan-Matu 2009). Semantically, the tool-oriented approach simply fails to clarify terms, because the tool constitutes a proposed solution, rather than a concept for consideration. In the ontological approach, every class receives an unambiguous label. In terms of extensibility, the tool-oriented approach imposes limits due to the tool's specific range of functionality, contrary to the ontological approach. Each tool also has its own repository information model, which the vendor may disclose or withhold, while ontologies are the province of end-users, rather than manufacturers. Accommodating the exchange of information among tools depends on the correctness of their linking protocols, while the ontological approach needs no special provision, short of the adoption by all parties of the same ontological framework. Finally, the tool-oriented approach imposes limits by appealing only to those end-users who wish to use the tool to manipulate those objects that the tool explicitly supports. The ontological approach imposes no limits on the intended audience (Niculescu and Trausan-Matu 2009).

We argue that it is feasible to extend Bera et al.'s (2011) approach to creating a visual ontology to the domain of software requirements negotiation, with a focus on human interaction between negotiating teams. The purpose of this application would be to reduce the sources of confusion that naturally emerge due to the disparate industrial backgrounds of the respective teams, which represent software engineers from a software development firm and project managers from a client firm, respectively. Accordingly, this paper aims to present a model of an ontological win-win approach to negotiating, as applied to the challenges of software requirements negotiation, by adapting Grünbacher's (2000) interpretation of Easy Win-Win to Bera et al.'s (2011) model of visual ontologies.

LITERATURE REVIEW

The potential application of visual ontologies to interpersonal decision-making originates in the domain of knowledge management systems, in which automated information processing is the essential consideration, but it is relevant to the full range of interpersonal interaction in real-time negotiating (Bera et al. 2011; Jureta 2011). Given the importance of the win-win model, specifically in the form of Grünbacher's (2000) Easy Win-Win model, as the foundation for adopting Bera et al.'s model of visual ontologies, it is apt first to lay out the Easy Win-Win model by itself. Grünbacher's (2000) original map of the process associated with Easy Win-Win constitutes a variation on the original win-win model, while leaving out only the cyclical element (*cf*. Figure 1, below). It thus provides detail addressing a single iteration of a multi-cycle process. Grünbacher's (2000) model therefore provides an amplified map of each cycle in the multi-cycle version of the standard win-win model and thereby provides space to show precisely how to apply the ontological component.

Bunge's ontological theory forms the basis for Bera et al.'s (2011) visual ontology (*cf*. Bera et al. 2010). As Fonseca (2007) explained, Bunge's ontological model is most widespread in its current use in information systems research. Bunge's theory is from the philosophical domain, so it has to do with the nature of knowledge in the broadest possible sense. Bunge's formulation of the search for knowledge posits that there are specific categories of knowledge that the specialist must seek, but there must first be a model available showing what those categories are (Bera et al. 2011). The answer depends on the discipline at issue. Each specialist will have a different set of categories to consider. Bunge's conceptualisation makes no effort to define those categories; rather, it identifies the common properties of all such conceptualisations, emphasising that every ontological construal has certain common properties, consistent with the philosophical concept of ontology in the realm of epistemology. Hence, the thinker in the discipline seeks to represent ideas in the form of a mathematically pure symbology and then to work with the resulting symbols by devising a special variety of algebraic logic.

Bunge's ontological system thus reduces all knowledge to a common substrate consisting of classes, properties, and things (or elements) (Table 1). All things (or elements) possess properties, so the ontologist must try to identify all key properties that apply to each identifiable thing. Moreover, properties may be intrinsic or mutual in nature. An intrinsic property is one that a given thing or element must have, by its nature. For example, a customer must have a name, if indeed the customer's name is important to a given set of transactions. (A customer in a standard retail environment need have no name.) A mutual property, by comparison, is one that only exists between two things or elements. For example, as Bera et al. (2011) suggested, a salary is an artefact of the relationship between an employee and an employer, so it is a mutual property, rather than an intrinsic one.

Table 1: Bera et al.'s Ontological Requisites (Source: Adapted from Bera et al. 2011)

Nomenclature	Description
Class	Entity class................Vertical mode of relation. Epiphenomenon of a given cluster of potential properties. Interacting class ....Horizontal mode of relation. Epiphenomenon of an emergent cluster of mutual properties.
Property	Intrinsic property ....Mode of differentiation. Potential state of a given class. Mutual........................Horizontal mode of relation. Potential state of a given interaction between classes.
Interaction	Involves ....Depends upon (acted upon by another class). Participates in.............Acts upon (has authority over another class state).
(Thing)	(There is no logical distinction between things and classes, except that things would constitute the lowest conceivable order of a class.)

In Bunge's conceptualisation, a property denotes an aspect of the current state of the thing or element, so a change in state results in a change in the identifiable property. Thus, ontologists would define properties as each possessing one or more potential states. In fact, a property is actually a label or category to suggest a particular variety of information. The fact that a customer has a name provides no clues as to the customer's name, for example, but knowing that this property must exist compels the practitioner to conduct the appropriate search. Thus, each property suggests a particular variety of information to seek. In this sense, the ontology shows the user what questions to ask.

Bera et al. (2011) explained that it would also be helpful to have a way to denote a change in state in a visual ontology. This kind of indication would suggest a temporal element to the ontology, which would in turn reflect the reality of ongoing negotiating parameters, which often change. Nevertheless, Bera et al. (2011) were able to demonstrate the effectiveness of the visual ontology without the aid of such an indicator, given the fact that the classes and linkages presented in the visual ontology exemplified in their work already imply the direction of effect of any change in any parameter. Thus, it is arguable that there is indeed no need to add an indication of a change in state, except possibly to construct contingency ontologies, by which negotiators might plan ahead of possible changes to software requirements specifications. The appendix to this paper compares a lexicon-based approach with that of ontological approach that incorporates all of the foregoing properties.

Although Bera et al. (2011) based their ontological conception on Bunge's model they excluded the reference to things or elements. Indeed, in the strictest construal of logic, there is arguably no need to depict things or elements separately from classes or categories, as these merely constitute the fundamental material of which a class consists. Classes often have subclasses, whilst being themselves also members of a superordinate class, so a subsidiary element in a class is conceivably a class as well, complete with the potential for further subdivision into subordinate classes. Bera et al.'s (2011) construal therefore leaves open the ontologist's question of whether to subdivide a given element, as every element thus has the potential for subdivision. In philosophy, there is an implicit need for identifying fundamental elements (things; *e.g.*, atoms), but in the practical world of negotiating, the distinction between an element and a class is academic, as any element can conceivably become a class, once it occurs to decision makers that it is possible to subdivide it further. In practical application, this provision allows negotiators to subdivide a thing or element at their discretion.

AN ONTOLOGICAL WIN-WIN MODEL

As previously indicated, the unique contribution of Grünbacher (2000) to the standard win-win model was the explication of a lexicon-building component to the negotiating process, which serves to formalise agreed-upon definitions of key terms and to specify their interrelations. The applicability of Grünbacher's (2000) model to the purpose of adding an ontological element to the negotiating process thus lies in the relationship between Bera et al.'s (2011) visual ontology and the initial lexicon that must emerge prior to the negotiators' organising their ideas in the form of a conceptual map. From this perspective, the visual ontology simply replaces the lexicon as an alternative way to formalise agreed-upon knowledge. However, it has the advantage of helping the negotiators identify what questions to ask, rather than leaving it to them to develop their shared frame of reference in an *ad hoc* way. Thus, rather than create lists of words with definitions, the negotiators collaborate to create an ontological map, depicting a common language of categories and relationships (Stevens et al. 2011) (Figure 1).

Figure 1 accordingly shows a depiction of Grünbacher's (2000) Easy Win-Win model alongside a conservative adaptation in the form of an analogous ontological win-win model. The latter image shows changes highlighted as shaded boxes (in addition to some changes in the flow elements between the boxes, which are easy to identify). This adjusted model alters three boxes, which consist of the first box (elaborate ontology), an ancillary box (map domain language to ontology), and the final box (map negotiation results to ontology). This selection of a limited number of boxes is the product of relevance, rather than parsimony, because logically there is only the most limited reason to modify any other box in the win-win model. The resulting changes and associated rationales are as follows:

1. Elaborate domain taxonomy → Elaborate ontology. In Grünbacher's (2000) conception, the initial phase of a negotiating round involves agreeing upon labels and definitions, to standardise and clarify the terminology that the negotiators will then use in the actual negotiating process. By comparison, the initial phase of the ontological win-win negotiating process consists of first drawing an ontological map, as indicated in the right-hand portion of Figure 1. The negotiators must then take the extra step of identifying formally the classes and relationship modes among all agents, products, and subsidiary processes that apply. The result is a visual ontology, which the negotiators will continue to use as their frame of reference during actual negotiation.

2. Capture domain language → Map domain language to ontology. In Grünbacher's (2000) conception, the negotiators continue to identify key terms to add to their lexicon as they deliberate. By comparison, the visual ontology creates the expectation to add or modify classes as needed, but it simultaneously serves as a map to reference during deliberation. The simple gesture of pointing to a class or tracing the linkage between classes communicates important information with minimal verbiage. Meanwhile, the context of the full map clarifies essential information without the need to interrupt negotiations to try to recap or recall assumptions or tentative conditions. In short, everything is visible. Moreover, with each subsequent round, recycling the ontology from the previous round facilitates the development of the ontological map itself. Thus, after its initial development, the mapped ontology continues to serve as the basis for the remainder of the entire negotiating process.

3. Map negotiation results to taxonomy → Map negotiation results to ontology. Strictly speaking, this final step is a continuation of the ongoing process of updating the ontological map during negotiation. While it is a discrete step in Grünbacher's (2000) Easy Win-Win model, the ontological version more precisely uses this step to formalise the completion of a negotiating round. This step is a prelude to the next iteration of the negotiation, at the next level of specificity. Mapping negotiation results onto the ontology therefore produces a visual ontology at the outset of the next iteration, simplifying the next sequence of activity.

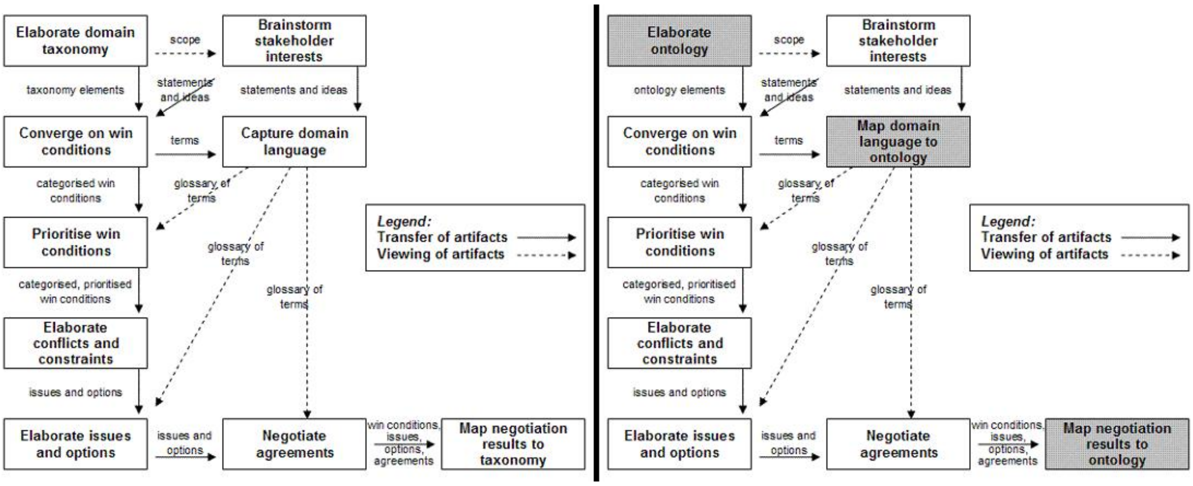

Figure 1: (a) Easy Win-Win (adapted from Grünbacher, 2000); (b) Ontological Win-Win (original)

In addition, one flow characteristic changes as follows:

4. Taxonomy elements → Ontology elements. By this point, this step is now self-explanatory, particularly as the cycle proceeds to the second and higher levels. The ontological approach seeks to preserve the essential elements of the taxonomical assumptions in the Easy Win-Win model. However, the visual representation, which must follow specific rules of symbology and accurately code each new element onto the evolving map, ensures that the taxonomy is more than merely an accident of brainstorming.

Developing a Meta-Ontology for Software Requirements Negotiation

Information ontologies, which translate lexicons semantically for usability across platforms, are necessary for harmonising usage criteria and avoiding system failure due to conflicting uses of unique terms (López et al. 2009). This observation extends into the area of concern of visual ontologies as well, by emphasising the potential sources of conflict among different conceptions of like terms among requirements negotiators, and the solution is the same, namely, the development of ontologies to harmonise the association between conceptions and terms. Interestingly, although most of the literature in the area of ontologies deals with information technology and therefore the implication that ontologies must ultimately be codifiable in the form of software, the guidance provided on the IT side of this literature nevertheless provides a range of usable protocols to adopt in the application of visual ontologies in human negotiation as well. Thus, while most approaches to ontological development focus on the practical domain and scope of usage, requirements negotiators must also provide an avenue for translating external functionality into internal architecture (Micucci et al. 2009). This observation highlights the importance of including people on any negotiating team who have deep knowledge of the underlying software, whether the negotiation process moves in the direction of adopting established software and extending it, or seeks to build new software altogether. As Micucci et al. (2009) noted, knowledge of the underlying architecture bears virtually no resemblance to that of the external functionality of any system.

Atanasova (2011) explained that three different strategies are available for constructing ontologies, namely, top-down, bottom-up, or a simultaneous combination. None of these is clearly superior to the others, a fact that reflects the complexity of the process. Assawamekin et al. (2010) specified that the construction of an ontology requires first the enumeration of requirements elements on the part of each stakeholder involved in the RN process. Upon establishing the requirements elements, the next step is then to organise them into an ontology, based on a preconceived meta-ontology. Ensan and Du (2011) explained that multiple ontologies constructed within an automated information environment may coexist with no necessity for further structuring, as long as they develop common protocols for exchanging information with one another. Although this proposition may seem to conflict with Niculescu and Trausan-Matu's (2009) view of the ontological approach to systems development, in fact it arguably obeys a principle of concentricity of systems, such that a given ontology may, after thorough development, exist as a class among other classes (*i.e.*, other ontologies) in a broader universe.

Jureta et al. (2008) detailed the framework for an ontology for developing service-oriented systems. The objective in the case study that served as the focal point for Jureta et al.'s (2008) ontology is a geographical information systems (GIS) application for deployment on websites. The critical feature of Jureta et al.'s (2008) conceptualisation is the establishment of quality criteria. The authors began by establishing the essential parameters of a quality dimension. These parameters include the quality dimension description, its purpose, the associated metric and unit of measurement, a formal definition (aggregate) of the noted property, the measurement source, and the equation corresponding to the measurement function. According to the authors, each quality characteristic upon which the negotiators agree is a composite function of one or more quality dimensions. While Jureta et al.'s (2008) example focuses on automation and therefore requires the precise translation of every quality dimension into a sequence of code that requires no further human judgment to effect, the emphasis on measurability translates easily into a critical component of the ontological win-win model, because the RN process must benefit from optimally objective ways to confirm the presence or absence of particular properties.

Ferreira et al. (2011) investigated the limitations of interoperability among disparate IT ontologies and focussed on defining contextual parameters to circumvent conflicts. While IT ontologies are likely to pose more intricate and hence more difficult questions of compatibility than will be the case with visual ontologies as discussed among human negotiators, Ferreira et al.'s (2011) observations nevertheless serve to justify the construction of a meta-ontology in the ontological win-win model, in that the negotiating parties thus avoid the trap of entering the negotiating room with fixed, possibly greatly detailed and hence incompatible ontologies that demand the painstaking process of reconciliation before any negotiating may begin. Nevertheless, at present it seems likely that a key best practice in the ontological win-win model will involve the separate elaboration of some kind of requirements ontology on the part of the using party prior to initiating negotiations.

Ferreira et al.'s (2011) solution to the problem of conflicting ontologies also heightens the importance of Jureta et al.'s (2008) contextual parameter. The ontological win-win model should therefore incorporate a process by which to establish context in this sense. To do this following Jureta et al.'s (2008) model, it is necessary simply to list all conceivable classes and build a matrix to indicate whether there is a relationship among any two classes. While this may become an excessively burdensome task beyond a given point of complexity, this approach nevertheless seems to provide at least a general expectation of the nature of the final approach adopted. Furthermore, adding Bera et al.'s (2011) specification of a distinction between the parameters of involvement (*involves*) and participation (*participates in*) permits the ontologist to specify the nature of the relationship, which conversely stimulates the ontologist's thinking as to what possible relationships might exist.

For example, a customer class has a relationship with several organisational agents and emergent properties simultaneously. Emergent properties in this sense refer to the products of the customer class's interaction with organisational agents, such as the creation of a purchase transaction, service agreement, or schedule. To answer the question of the participation parameter, the ontologist asks over whom the customer has authority, because Bera et al. (2011) specified that the participation parameter involves one class's having authority over another, in contrast to mere involvement, which instead might imply dependence. After this, the ontologist asks over what the customer has authority. In fact, the customer class typically has no authority over any person in the service-providing organisation, but this class will have authority over the products of negotiated decisions, such as the classes of transaction, purchase, or inquiry.

Affected Process Steps in the Ontological Win-Win Model

Slimani et al. (2011) distinguished among three approaches to the use of ontologies in information technology applications, which arguably correspond to analogous approaches in the use of visual ontologies. These consist of the mono-ontology approach, the multiple-ontology approach, and the hybrid ontology approach. The mono-ontology approach consists of approaching all development based on a single ontology, on which all participants have agreed. The multiple-ontology approach permits the presence of multiple guiding ontologies, each driving a particular course of development, but they require protocols for transferring information among themselves. The hybrid approach permits the existence of a foundational ontology, perhaps in the sense of a meta-ontology, whereof multiple ontologies are derivatives with their own respective protocols. The ontological win-win approach to software requirements negotiation focuses most squarely on the mono-ontology approach, because it is necessary to emphasise strong consensus over the terminology during the course of negotiation, just as is the case with Grünbacher's (2000) Easy Win-Win approach.

Recalling the two models shown in Figure 1 (above), introducing the ontological element into Grünbacher's (2000) Easy Win-Win negotiating model affects three process steps. These occur at each point at which the original model moves to establish or further develop the evolving taxonomy. The ontological perspective modifies this taxonomical development by containing it within a formal conceptual structure, by which to cue stakeholders to identify all necessary knowledge, according to the meta-ontology provided at the outset of the process. This adjustment to the original model thus converts the relatively loose brainstorming process into a more highly structured and accurately targeted process of seeking those elements of knowledge indicated by the meta-ontology. Thus, brainstorming continues to occur, but with a powerful focus on each individual demand for knowledge specified by the meta-ontology, rather than in haphazard fashion. Under ordinary circumstances, brainstorming creates a disorganised assemblage of ideas, which place a subsequent burden on collaborators to build into a coherent structure to guide the rest of the process. In the ontological application, brainstorming begins with the requisite organisation in place and therefore eliminates most sources of error that are likely to occur in the traditional model.

Elaborate Ontology

The meta-ontology must use the tools provided by Bera et al. (2011), such that the only symbols allowable are those that represent class, property, and relationship. For Bera et al. (2011), classes come in two basic varieties, including originating classes, which are usually human or organisational actors in the system, and emergent classes, which constitute the tangible or durable product of the interaction between two other classes. This latter observation is important, for example, in the question of what constitutes the relationship between a customer service representative and a customer. The interaction may produce a product (and indeed it does, as evidenced by the fact of a sale). Thus, while the negotiators will identify key stakeholders, which will in turn imply actors (*e.g.*, a manufacturing company as a stakeholder implies the corporate buyer as a stakeholder in the buying process), every potential interaction between actors must constitute grounds for considering the possibility of an emergent product or class. In turn, any emergent product requires its own properties.

However, the identification of class, property, and relationship is insufficient by itself. This is because it is impossible to identify these categories of knowledge without first circumscribing the problem domain. In turn, as previously noted, the problem domain refers to the intersection of the entity domain (*i.e.*, the capabilities of the entity or organisation in question) and the operational domain (*i.e.*, the functionality sought by the entity or organisation in question). Toward this end, collaborators must first work to understand the ontology and its associated rules. Each proposed addition to the ontology requires fitting the new idea into the basic framework of classes, properties, and interactions. As long as a new idea possesses specific information about all three ontological requisites, it is amenable to further agreement among the parties in the brainstorming step. Each new idea must also benefit from answering the question of whether and how it affects all pre-existing components of the ontology. This action requires a methodical review of possibilities, which the different negotiating parties may undertake separately, after which a comparison of results and further modification of detail becomes easy.

Map Domain Language to Ontology

In Grünbacher's (2000) Easy Win-Win structure, the "capture domain language" step involves codifying the key terms used by all stakeholders, to permit necessary revisions in the use of language so that all stakeholders adopt the same terminology (Grünbacher 2000). In the ontological application, this process has been ongoing from the beginning, because every action has occurred on the ontological map, as it were. Therefore, the step in which to map the domain language onto the ontology really refers to the step that involves concluding and agreeing upon the working ontology.

There will be room for further refinement of the ontology through the process, but this agreement is the appropriate step prior to identifying win-conditions, because the language in which the parties express the win-conditions must be identical. This step is also an improvement over Grünbacher's (2000) Easy Win-Win model in its original form, because there is less risk that the agreed-upon terminology will hide any sources of misunderstanding that will only become apparent later. Accordingly, the middle model in Figure 2 illustrates the sequential steps involved in the process of mapping the domain language to the ontology. At this point, the negotiators have already adopted the win-conditions and an understanding of stakeholder interests. However, win-conditions may conflict with stakeholder interests, as each is a matter of prioritising, based on a sense of judgment with regard to weighting alternatives. Therefore, the sub-process includes an ancillary step of reconciling conflicting elements.

Map Negotiation Results to Ontology

In the original Easy Win-Win structure, the "map negotiation results to taxonomy" step involves enhancing the working taxonomy by adding detail, enriching explanation, and adjusting specific terms to fit the evolving process (Grünbacher 2000). In the ontological application, this step involves comparing the negotiation results against the working ontology and formally agreeing on adjustments to the latter to reflect the former. This creates a finalised ontology to support the next iteration of the Win-Win process, which originally began with a meta-ontology. The additional information generated for the evolving ontology in this way dramatically enhances the level of organisation of the RN taxonomy and minimises the error rate geometrically in the process.

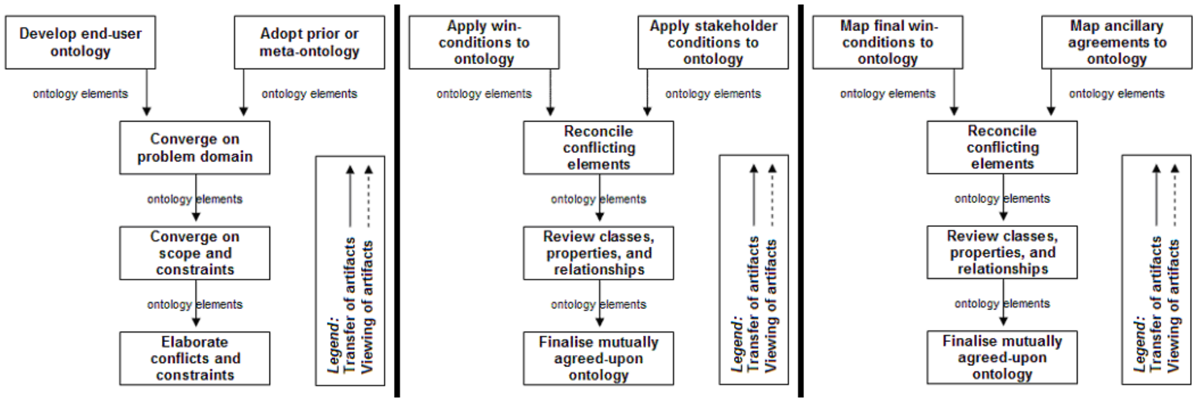

Figure 2: (a) Ontological elaboration; (b) Mapping domain language; (c) Mapping negotiation results

The third model in Figure 2 shows the sequential process in carrying out the final mapping of negotiated results onto the developing ontology. Although this step may seem redundant, given the fact that prior steps have already mapped requirements onto the ontology with a good level of structure, this final step is critical, because there is in fact a subsequent step in most cases, consisting of the next iteration of the entire process. Therefore, it is important to establish as much strength in the resulting ontology as possible. In turn, the next step will be identical to that depicted in the first model, despite the fact that the ontology appears to exist already. This is because the next iteration of the cycle will involve a new level of detail, which the current ontology only indirectly addresses as yet. Thus, the end-user must again first elaborate a complete ontology, based firmly on that which emerges from the sub-process depicted here, but that again turns attention back to the end-user's priorities. That step is therefore also a chance to rethink the entire scheme without having to engage simultaneously in negotiation.

DISCUSSION

This paper has argued in favour of adapting Bera et al.'s (2011) conception of ontological mapping to Grünbacher's (2000) Easy Win-Win model, to help expedite the attainment of common understanding among parties in requirements negotiation. A key point of emphasis regarding this integration of models is the role of visual representations in building intuitive understanding more rapidly than is likely to be feasible using only semantic representations. The integrated model presented in this paper takes the conservative approach of preserving as much of Grünbacher's (2000) Easy Win-Win model as possible, while altering selected junctures with strictly ontological assumptions. Thus, the resulting model treats the latter as the essential process model, necessary for providing sequential steps for practical application. The ontological adjustments therefore constitute changes in the core means of conceptual communication, rather than in the steps to follow.

In consideration of the theoretical reasoning that might underlie the role of conceptual models of this kind in increasing efficiency in requirements negotiation process and effectiveness in the resulting outcomes, systems theory (in the general sense of the paradigm of self-organising complexity) provides a basis for understanding the connections between interpersonal processes and higher-order organisational outcomes. Researchers in this paradigm have so far developed three key constructs to explain information exchange in a direction-neutral (*i.e.*, dependency-neutral) way. These theories consist of leader-member exchange, team-member exchange, and fractal vertical polarisation (Voss and Krumwiede 2012). These theories may thus offer insights of value to the further refinement of Bunge's ontological model, which exploits organisational theory explicitly for this purpose.

Practical outcomes from this line of inquiry may include the creation of training programs to enable face-to-face negotiators to use visual ontologies to enhance their negotiating efficiency, the provision of optimal conceptual tools to enable consulting agencies to mediate negotiations, and improvements in the effectiveness of the win-win model itself in the context of requirements negotiation. These three trajectories of development are realistic, in that they suggest the possibility of improvement of existing systems, rather than seeking to introduce a completely new system that may lack firm connections to theory or proven approaches. They also suggest the possibility of measurement, in the sense that RN efficiency is clearly measurable (*e.g.*, as a product of the cost of time and resources, compared to the marketable benefit of a resulting software product). Meanwhile, the relative effectiveness of the traditional win-win model, as compared to that of an enhanced win-win model that includes an ontological element, is likewise measurable in experimental settings by virtue of observable error rates and other process measures.

Lastly, the importance of the present project rests in the persistence of error in requirements negotiation (Bera et al. 2011; Recio-Garcia et al. 2009; Vieregge and Quick 2011). As firms experience increasingly intense competition to keep up with the latest developments in software engineering, it becomes increasingly vital to reduce error in negotiation. The information available to a competing software development firm is more difficult to segment and control than in the past. Firms are therefore less capable of exploiting temporary disequilibria in information flow across the industry as their primary mode of maintaining competitive advantage. Instead, they must increasingly assume that other firms know what they know, so the only advantage remaining is that of actual synergies with negotiating partners. This fact suggests that the win-win model itself is inevitably becoming a more important premise in requirements negotiation, and that obstructions to information flow between the parties to negotiation are an ever more important source of competitive disadvantage. Research into practical models that can substantially reduce such obstructions is therefore of rapidly growing importance in today's software engineering context.

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APPENDIX

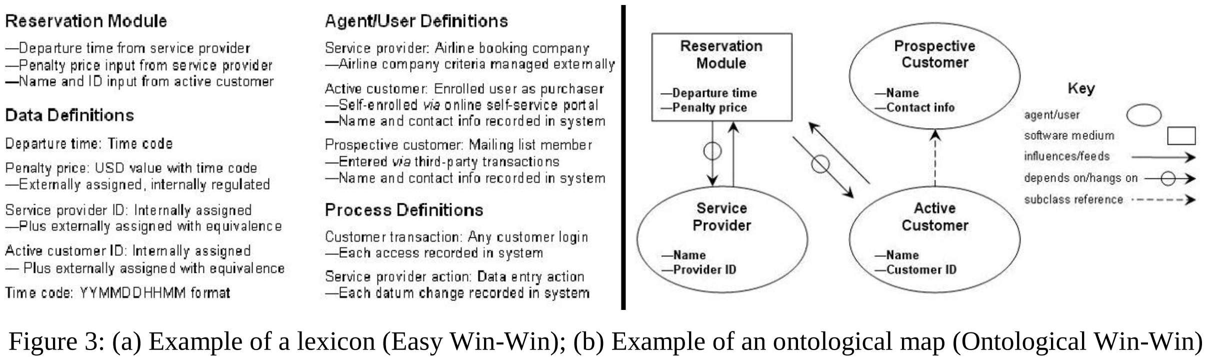

Figure 3: (a) Example of a lexicon (Easy Win-Win); (b) Example of an ontological map (Ontological Win-Win)

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